Remarks

Claims 5-9 have been canceled, and claim 1 has been amended. Claims 1-4 and 10-14 remain in the application. Re-examination and reconsideration of the application are respectfully requested.

Claims 1-4 and 10-14 are rejected under 35 U.S.C. §103(a) as being unpatentable over Nojima (U.S. Patent No. 5,812,355) in view of Oyama et al. (U.S. Patent No. 4,878,147). Nojima relates to an electric gun driver for controlling a solenoid with a fluid dispenser. Referring to Fig. 1, a gun driver 10 operates with different line voltages ranging from 100-240 volts AC and at frequencies of 50-60 Hz. A switch mode power supply 18 receives a wide range of line voltages 19 and generates an isolated supply voltage 20 for use by a microcontroller 40 within a control circuit 11. The microcontroller 40 provides a current reference signal on an output 44 connected to a hysteresis band modulator 46 that receives a current feedback signal on an input 48. The current feedback is adjustable by the microcontroller 40 via output 90, and the current reference signal is determined by the microcontroller 40 as a function of operator selectable inputs. For example, the operator can designate the duration of the pull-in or peak current and the duration of the hold current, so that the gun operation can be adapted to different fluid viscosities and other application variables. The hysteresis band modulator 46 modulates the operation of the transistor switch 54, so that a desired drive current is supplied to the solenoid 14 of the dispenser 12 independent of the magnitude of the line voltage 19. The duration of the pull-in or peak current is selectable by the operator, so that the gun operation can be adapted to different fluid viscosities and other application variables. However, once the peak and hold current durations are selected, they remain fixed and are not affected by the magnitude of the line voltage.

In citing Oyama et al., the Office Action references column 1, line 12 to column 2, line 18. That portion of Oyama et al. describes the operation of a Japanese Laid-open Application No. 62-145619 ("the '619 Application"), copy enclosed. In order to better understand the operation of the '619 Application,

Applicant is also enclosing a translation. The '619 Application relates to an electromagnetic coil excitation circuit that drives a single type of coil in response to a range of supply voltages, for example, 100 volts to 200 volts, as well as a range of supply frequencies, for example, 50 Hz to 60 Hz.

Referring to Fig. 1, an output from a rectifier 2 is connected to a coil 6, and current through the coil is determined by a switch 5 being driven by a control circuit 4. The control circuit 4 is shown in more detail in Figs. 2 and 3, and Figs. 4 and 5 illustrate waveforms in response to supply voltages of 100 volts and 200 volts, respectively. Waveforms j and k of Fig. 6 illustrate current through the coil 6 in response to respective supply voltages of 100 volts and 200 volts. For a period of time represented by t_2 in waveform c of Figs. 4 and 5, current is initially rapidly applied to the coil 6 and is maintained at a larger magnitude as shown by waveforms j and k of Figs. 4 and 5, which causes a movable core of the coil 6 to start moving. The core moves through a displacement or gap as shown by curve i of Fig. 6. After the core is pulled-in, the current through the coil 6 is then diminished to a lesser, relatively constant holding or retention value as represented by the right ends of the waveforms j and k. Even though the applied voltages are substantially different, 100 volts versus 200 volts, in waveforms j and k, the initial, larger currents and the subsequent lesser, retention currents are about the same.

In operation, referring to Figs. 2 and 3, a comparator 46 has one input connected to a circuit 41 integrating the rectified supply voltage, waveform e of Figs. 3 and 4; and a second input is connected to a sawtooth wave generator 44, waveform d of Figs. 3 and 4. The comparator 46 provides a serial train of pulses, waveform f of Figs. 3 and 4, which has respective on-times that are inversely proportional with the integrated voltage magnitude, waveform e of Figs. 3 and 4.

The output of comparator 46 is connected to switching circuit 47 comprised of AND gates 71, 72. AND gate 71 is also connected to an output of delay circuit 43, waveform c of Figs. 3 and 4, which determines the end of t_2, that

is, when the current switches from an initial higher value to a lower retention value. Therefore, when waveform c is low, it is inverted to high by inverter 73; and AND gate 71 passes the output of comparator 46 to the switch 5, thereby operating the switch 5 in accordance with waveform f of Figs. 3 and 4. That operation supplies a larger current magnitude to the coil 6, that is, the left hand portions of waveforms j and k of Fig. 6. When waveform c of Figs. 3 and 4 from the delay circuit 43 changes state, the AND gate 71 changes state; and the switching circuit 47 disconnects the output from the comparator 46 from the switch 5. However, AND gate 72 is connected to an output of a coil retention drive 45, operating the switch 5 with pulses represented by waveform g of Figs. 4 and 5 to provide a lower magnitude current to the coil 6 as represented by the right sides of current waveforms j and k of Fig. 6. Thus, the output of the switching circuit 47 is represented by the waveform h of Figs. 4 and 5.

A prima facie case of obviousness is not made because Nojima, Oyama et al., the '619 Application neither alone nor in combination disclose or suggest the claimed inventions. All of the independent claims require an output signal be provided to a solenoid, which has an initial peak current of a variable duration followed by a hold current, wherein the duration of the initial peak current varies as a function of the output voltage magnitude of the power supply. In the '619 Application, different supply voltage magnitudes result in the switch 5 being pulsewidth modulated by the waveform h of Figs. 3 and 4 to control the average current through the coil. The duration t_2 of the initial current applied to the coil is determined by the delay circuit 43, waveform c of Figs. 3 and 4; and that duration of t_2 is fixed and does not change with the application of different supply voltages.

There is nothing in Nojima, Oyama et al. or the '619 Application that teaches, suggests or motivates one to provide a solenoid drive for a fluid dispenser that produces a peak current having a duration varying as a function of the supply voltage magnitude. Therefore, Applicant submits that claims 1-4

and 10-14 are patentable and not obvious under 35 U.S.C. §103(a) over Nojima in view of Oyama et al.

Claims 1-4 and 10-14 are rejected under 35 U.S.C. §103(a) as being unpatentable over Nojima in view of Ohtsuka. Ohtsuka relates to an electromagnetic contactor that can be connected to different voltages and also controlling movement of a movable iron core in order to mitigate the physical impact of the movable core colliding with a fixed iron core. Referring to Fig. 3 and col. 9, lines 20-30, a timer circuit 16 provides outputs to both a closing pulse computing circuit 17 and a maintenance pulse computing circuit 18. Thus, the timer circuit 16 controls the duration of a closing operation, T1, (curve (e) of Fig. 6) having a larger current, after which a lower maintenance current is applied to the coil. It should be noted that the closing The operation of the timer circuit 16 is further described at col. 12, line 65 - col. 13, line 8 and elsewhere, and Applicant has been unable to find any description in Ohtsuka et al. that indicates that the duration of T1 is adjustable as a function of a power supply voltage magnitude.

In addition, it should be noted that the '619 Application discussed above is referenced in the Background of Ohtsuka. Referring to col. 2, line 8, Fig. 10 of Ohtsuka is a replication of Fig. 4 of the '619 Application. Curve h of Fig. 10 in Ohtsuka represents the pulse width modulated signal that is provided to the switching element 5 of Fig. 3 in the '619 Application. Curve h is comprised of first pulse width modulated pulses that occur over the time period t_0+t_1 (curve i of Fig. 10), so that the average voltage magnitude is inversely proportional to the applied voltage. After the pull in or closing time, In addition, it should be noted that the '619 Application discussed above is referenced in the Background of Ohtsuka. Referring to col. 2, line 8, Fig. 10 of Ohtsuka is a replication of Fig. 4 of the '619 Application. Curve h of Fig. 10 in Ohtsuka represents the pulse width modulated signal that is provided to the switching element 5 of Fig. 3 in the '619 Application. Curve h is comprised of first pulse width modulated pulses that occur over the time period t_0+t_1 (curve i of Fig. 10), so that the average voltage

magnitude is inversely proportional to the applied voltage. After the pull in or closing time, t_0+t_1, second pulse width modulated pulses apply a lesser, maintenance voltage to the coil, so that the coil can maintain the iron core in its switched state.

Ohtsuka, at column 3, lines 40-59, describes the disadvantages of '619 Application as being unable to distinguish between AC and DC power supplies and also being unable to execute minute control of the iron core.

It is also useful to compare the waveforms of Fig. 6 of Ohtsuka with the prior art waveforms of Fig. 10. In Fig. 6, curve (e) represents the pulse width modulated signal that is provided to the second switching element 2 of Fig. 2. That signal is substantially similar to the curve h of Fig. 10 representing the pulse width modulated signal supplied to the switching element in the '619 Application. In other words, during a closing period represented by T_1, the Ohtsuka second switching element is operated by a pulse width modulated signal having an average voltage magnitude that varies inversely with the applied voltage. After the closing period T_1, the Ohtsuka second switching element 2 is driven by a pulse width modulated signal having a substantially lesser average voltage magnitude. The resulting current in the coil is illustrated by curve (f) of Fig. 6 in Ohtsuka, which is substantially similar to the curves j and k in Fig. 6 in the '619 Application.

Applicant submits that descriptions in Ohtsuka relating to varying a pulse width refer to the pulse widths g, h, i illustrated in curve (e) of Fig. 6 during the time T_1. Varying those pulse widths is effective to change the average voltage magnitude applied to the switching element. However, like the '619 Application that has a constant closing time t_0+t_1, varying those pulse widths in curve (e) of Fig. 6 is not effective to change the duration of T_1, which is controlled exclusively by the timer circuit 16 of Fig. 3.

A prima facie case of obviousness is not made because Nojima and Ohtsuka et al. neither alone nor in combination disclose or suggest the claimed inventions. Each of the independent claims requires an output signal be

applied to a coil or solenoid having an initial peak current with a variable duration followed by a hold current, wherein the duration of said initial peak current varies as a function of the power supply voltage. As described at page 10 of the application, line 11 through page 13, line 5 and elsewhere, referring to Fig. 4, the PWM 130 is operated at a set, for example, 100%, duty cycle for the duration of the peak current. A delay circuit 132 controls the duration of the peak current as an inverse function of the power supply voltage. Thus, the greater the power supply voltage, the shorter the duration of the peak current. At the end of the peak current duration, the duty cycle of the PWM 130 is reduced to provide the hold current to the solenoid.

In Nojima, the pull-in or peak current duration is selectable by the operator, but once selected, is fixed during the operation of the solenoid. In Ohtsuka, as shown in curves (e) and (f) of Fig. 6, the duration of the higher magnitude closing current is fixed and controlled by the operation of timer circuit 16 as shown by T1 of curve (e) of Fig. 6. Applicant is unable to find any disclosure in Ohtsuka that describes or suggests varying the duration T1 of the closing current prior to the initiation of the maintenance current.

A prima facie case of obviousness is not made because Nojima and Ohtsuka et al. are directed to different problems than the claimed invention. Nojima is directed to providing a power supply that can be connected to a range of line voltages. Ohtsuka is directed to providing an electrical contactor that can be connected to different voltages as well as mitigating the physical impact of the movable core colliding with a fixed iron core.

In contrast, the claimed invention is directed to improving the performance of a dispensing valve by simply using a higher voltage power supply without having to replace a valve driver circuit and without operating the coil inefficiently. Improving the performance of a dispensing valve often means operating the dispensing valve at a higher dispensing rate, for example, increasing the dispensing rate from 10 cycles per second to 20 cycles per second. As discussed at page 14, lines 25-29, "...with the higher voltage power

supply, the duration of the peak current is automatically shortened. By shortening the duration of the peak current to match the response time of the dispensing valve, no more current than is required is provided to the coil and therefore, no more heat than necessary is generated by the coil."

Applicant submits that none of the cited references describe, suggest or motivate one to shorten the duration of the peak current as required by the claims.

Therefore, Applicant submits that claims 1-4, and 10-14 are patentable and not obvious under 35 U.S.C. §103(a) over Nojima in view of Ohtsuka.

Claims 1-4 and 10-14 are provisionally rejected under the judicially created doctrine of obviousness-type double patenting as being unpatentable over claims 3, 4, 16, 22 and 23 of copending Application Serial No. 09/702,493. Applicant is filing herewith a Terminal Disclaimer and respectfully requests that this provisional rejection be withdrawn.

Applicant submits that the application is now in condition for allowance and reconsideration of the application is respectfully requested. The Examiner is invited to contact the undersigned in order to resolve any outstanding issues and expedite the allowance of this application.

Respectfully submitted,

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(54) Title of invention: COIL EXCITATION CIRCUIT OF AN ELECTROMAGNETIC CONTACTOR

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SPECIFICATION

1. Title of the invention: Coil excitation circuit of an electromagnetic (or solenoid) contactor

2. Patent Claims

According to Client's instruction, the Patent Claims were not translated.

3. Detailed explanation of the invention

Area of application of the invention

This invention relates to an electromagnetic driver that uses a switching element and, especially, to an electromagnetic driving circuit suitable for an electromagnetic contactor that can be operated at two different voltages.

Background of the invention

As disclosed in Laid-Open Patent S55-103684, for example, a conventional electromagnetic driver using a switching element that generates a drive-starting pulse of set width by first adding the integral of the drive control signal of set width to a voltage frequency conversion circuit and thereafter generates a circuit control pulse, the width of which decreases in sequence while the drive control signal is being added.

Also, as shown in Utility Model S59-38016, a coil is connected to the full wave rectifier circuit via a thyristor, an oscillation circuit is formed by using a transistor, PUT, etc., a circuit is composed to connect the thyristor by the output of the said oscillation circuit, and the charging circuit of the capacitor of the oscillation circuit is switched to allow a large current flow as the starting current from switch-on to a set time, and a small current as the retention current after the set time. However, in the said conventional example, although compensation for the change in source voltage is disclosed, the idea of common use of the coil for two different voltages, such as 100 V or 200 V and 200 V or 400 V is not disclosed. Furthermore, a composition for common use of the coil for two voltages, in which a pulsed voltage is added to the coil and the pulse width of the said voltage is changed according to the input voltage, was being studied before arrival at this

invention and a patent was applied for under Application No. S59-260695. However, in this application, the pulse width and the frequency generated for a given input voltage are constant. Therefore, to apply 200 V and 400 V as input voltage to the coil for 100 V, the electric consumption of switch-on increases if the pulse width is set too large to reduce the switch-on time and the coil can burn out or the core can wear due to excess current. When the connection time is decreased in order to prevent such problems, the switch-on time increases.

Objective of the invention

This invention offers an electromagnetic driver that uses the same coil for a wide range of voltages, such as AC 100 V-250 V.

Outline of the invention

[This paragraph on Japanese page 78 is a repeat of Claim 1, not translated according to client's request. - Translator]

According to a preferred embodiment, the said switch-on signal generating means is the 1st oscillation circuit that generates a pulse series, the ON-duty [sic] of which decreases gradually, based on the output of the said integration circuit; the said retention signal generating means is the second oscillation circuit that generates a constant frequency, and generates a pulse series, the pulse width which changes according to the level of output voltage of the said integration circuit.

According to another preferred embodiment, the said switch-on signal generating means is the 1st oscillation circuit that generates a pulse series, the ON-duty of which decreases gradually according to the output of the said integration circuit, and the said retention signal generation circuit is the said delay circuit.

Practical Examples

Practical examples of this invention are explained below. The first practical example is explained with the aid of Figures 1-6.

Figure 1 is a block diagram of the circuit of this practical example. In the figure, 1 is the input source, 2 is a rectifier circuit, 3 is the source of control circuit 4, 5 is a transistor, i.e., a

switching element, 6 is an electromagnetic coil and 7 is a free-wheeling diode. Input source 1 in this example is a 50 Hz or 60 Hz commercial source.

Figure 2 is a block diagram of drive control circuit 4. In this example, the circuit comprises voltage detection circuit 42, signal delay circuit 43, input voltage integration circuit 41, sawtooth-wave generation circuit 44, comparison circuit 46, coil retention drive circuit 45 and output switching circuit 47.

Figure 3 shows the specific circuit of this example and the main waveforms are shown in Figures 4-6. Incidentally, as an example, Figures 4 and 5 show the waveforms for a 100 V and 200 V input source, respectively. In this example, rectifier circuit 2 is composed of diode bridge D_1 and the AC input side of bridge D_1 is connected to input source 1 and the minus side of the DC output side is grounded (hereafter, GND) and the plus side is connected to source circuit 3 and electromagnetic coil 6 and input terminals of integration circuit 41, voltage detection circuit 42 and signal delay circuit 43 and it generates waveform α of Figures 4 and 5.

Source circuit 3 is a known stabilizing source circuit and it stabilizes the output voltage of rectifier circuit 2 and supplies it to voltage detection circuit 42, signal delay circuit 43, sawtooth wave generating circuit 44 and coil retention drive circuit 45 as their source voltage Vcc, respectively.

Next, the composition and functions of these circuits are explained.

Voltage detection circuit 42 is composed of resistor R_{21}, one end of which is connected to the plus side input of comparator Q_{21} and the other end is connected to the output of rectifier circuit 2; smoothing capacitor C_{21} connected between the plus side input of comparator Q_{21} and GND; resistor R_{22} that is connected parallel to smoothing capacitor C_{21} and discharges an accumulated charge of capacitor C_{21}; resistor R_{23}, one end of which is connected to the minus-side input of comparator Q_{21}, Zener diode ZD_{21}, the cathode of which is connected to the minus side of comparator Q_{21} and the anode is connected to the GND; and buffers Q_{22}, Q_{23} which are connected to the output terminal of comparator Q_{21} and have an open collector output respectively, and the said outputs are connected to the input side of capacitor C_{11} of integration circuit 41 and the input side of capacitor C_{31} of signal delay circuit 43.

Voltage detection circuit 42 evaluates the level of the voltage generated in rectifier circuit 2 and it connects the open collector output of buffers Q_{22}, Q_{23} when the voltage is insufficient for attraction of electromagnet 6 and it short circuits both ends of capacitor C_{11} of integration circuit 41 and capacitor C_{31} of signal delay circuit 43 to put the integration circuit and the signal delay circuit 43 in a waiting state.

When the output voltage of rectifier circuit 2 is sufficient to attract electromagnet 6, the open collector outputs of buffers Q_{22}, Q_{23} are not connected.

Thereby, capacitor C_{11} of integration circuit 41 and capacitor C_{31} of signal delay circuit 43 are added to output b of Figures 4 and 5 and they start charging for the operation of integration circuit 41 and signal delay circuit 43. Integration circuit 41 is composed of resistor R_{11}, one end of which is connected to the plus side output of rectifier circuit 2 and the other end is connected to GND via capacitor C_{11} and resistor R_{12}, which is connected parallel to capacitor C_{11}. It commences integration of a full rectifier waveform of rectifier circuit 2 according to the open collector output of buffer Q_{22} and generates output d of Figures 4 and 5.

In this example, the switch-on signal generation means is 1st oscillation circuit 40, composed of sawtooth-wave generation circuit 44 and comparison circuit 46. Sawtooth-wave generation circuit 44 is a known circuit and it produces sawtooth waveform d of Figures 4 and 5 by applying positive feedback to amplifier Q_{41}. This sawtooth wave has a frequency of approximately 300 Hz-500 Hz. In the sawtooth-wave generation circuit 44, R_{41}-R_{45} are resistors, C_{41} is a capacitor and D_{41}, D_{42} are diodes.

Comparison circuit 46 is composed of comparator Q_{61}. The output of sawtooth-wave generation circuit 44 is connected to the plus side input of comparator Q_{61} and output of integration circuit 41 is connected to the minus side input for voltage comparison of these waveforms, and it produces pulse series f of Figures 4 and 5.

As shown above, the pulse width of the pulse series of 1st oscillation circuit (f of Figures 4 and 5) changes with the output voltage of integration circuit 41. The pulse width is wide when the output of the integration circuit 41 is started and it is narrow when the output of rectifier circuit

2 is near the peak of the full rectified waveform, as the output voltage of integration circuit 41 increases. Furthermore, the pulse width is wide when it is near the valley.

In this example, the retention signal generation means is the 2nd oscillation circuit 45, which is composed of a sawtooth-wave oscillation circuit that is the positively fed-back amplifier Q_{51} and comparator Q_{52}. The 2nd oscillation circuit 45 compares outputs of the sawtooth-wave generation circuit and integration circuit 41 by the use of comparator Q_{52}, and it generates a pulse series of narrow pulse width when the output voltage of integration circuit 41 is high and a pulse series of wide pulse width when the output voltage is low (g of Figures 4 and 5).

In the 2nd oscillation circuit 45, C_{51} is a capacitor and R_{51}-R_{56} are resistors. Incidentally, the pulse series of the output of 2nd oscillation circuit 45 is used to set the coil retention circuit so that the constants of the elements of oscillation circuit 45 are such that the ON-duty of the 2nd oscillation circuit is smaller than that of the output pulse series of 1st oscillation circuit 40. In this example, the frequency is longer than that of pulse series f, but the frequency can be raised to approximately 20 kHz. Signal delay circuit 43 is composed of a first time-constant circuit consisting of resistor R_{31} and capacitor C_{31}, protection resistors R_{33} and Zener diode ZD_{31}, protection resistor R33 for Zener diode ZD_{31}, pull-up [sic] resistor R_{34} for the output of comparators Q_{31}, comparators Q_{31}, Q_{32}, pull-up resistor R_{36} for the output of compensator Q_{32}, and a 2nd time-constant circuit composed of resistor R_{35} and capacitor C_{32}.

One end of resistor R_{31} of the first time constant circuit is connected to the plus side output of rectifier circuit 2 and the other end is connected to one end of capacitor C_{31}. The other end of capacitor C_{31} is connected to GND. In addition, resistor R_{32}, for discharging of the residual charge, is connected parallel to capacitor C_{31}.

The connection point between resistor R_{31} and capacitor C_{31} is connected to the open collector output of buffer Q_{23} of voltage detection circuit 42 and to the plus side input of comparator Q_{31}. The anode of Zener diode ZD_{31} is connected to GND and its cathode is connected to Vcc via resistor R_{32}. The minus side input of comparator Q_{31} is connected to the cathode of Zener diode ZD_{31} and kept at a constant voltage. Comparator Q_{31} has an open collector output and its output is connected to Vcc via pull-up resistor R_{34} and to GND via resistor R_{35} and capacitor C_{32}.

The minus side input of comparator Q_{32} is connected to the cathode of Zener diode ZD_{31} and the plus side input is connected to the connection point between resistor R_{35} and capacitor C_{32}. Comparator Q_{32} has an open collector output and the output is connected to Vcc via pull-up resistor R_{36} and to output switching circuit 47. Thereby, the open collector output of buffer Q_{23} becomes unconnected when the output of rectifier current 2 is sufficient to attract electromagnet 6 and the output of rectifier circuit 2 is charged in capacitor C_{31} and the voltage of capacitor C_{31} increases. When the voltage exceeds the standard voltage of Zener diode ZD_{31}, the open collector output of comparator Q_{31} becomes not connected. Thereby, capacitor C_{32} is charged via resistor R_{35} and its voltage increases. When the voltage exceeds the standard voltage of Zener diode ZD_{31}, the open collector output of comparator Q_{32} becomes disconnected and the output is supplied to output switching circuit 47.

As shown above, signal delay circuit 43 generates output c of Figures 4 and 5 after the open collector output of buffer Q_{23} becomes disconnected and after delay time t_2, due to the 1st and 2nd time constant circuits. This delay time is set as switch-on time t_0 of the coil plus a small time delay t_1.

The output switching circuit is composed of inverter Q_{73}, AND gates Q_{71}, Q_{72} and the OR circuit composed of diode D_{71} and D_{72}. AND gate Q_{71} is a two-input AND gate and one of its inputs is the output of 1st oscillation circuit 40 and the other input is the output of signal delay circuit 43 via inverter Q_{72}. Thereby the output is generated by AND gate Q_{71} when the output of signal delay circuit 43 is at level L and the output of the 1st oscillation circuit is at level H. AND gate Q_{72} is a two-input AND gate and one of its inputs is the output of 2nd oscillation circuit 45 and the other is the output of signal delay circuit 43. Thereby, AND gate Q_{72} generates an output when the input of signal delay circuit 43 is at level H, and the output of the 2nd oscillation circuit is at level H.

The outputs of AND gates Q_{71} and Q_{72} are connected respectively to the base of transistor 5 via the OR circuit composed of diodes D_{71}, D_{72}. Since signal switching circuit 47 is composed as above, the output of 1st oscillation circuit 40 is supplied to the base of transistor 5 when the output of the signal delay circuit is at level L and the output of signal delay circuit 43 is supplied to the base of transistor 5 when the output of signal delay circuit 43 is at level H.

In Figures 4 and 5, i indicates the stroke of the moveable core (not shown), which is attracted by coil 6. The moveable core is provided with a set gap G as against fixed core (not shown) and the gap becomes zero when it is attracted by the fixed core due to excitation of coil 6 and after switch-on time t_0.

Figure 6 shows the output of voltage detection circuit 42, switching circuit 47 versus the current waveform of coil 6 versus the stroke of moveable core relationship. In the figure, b, c and i are the output of voltage detection circuit 42, the output of switching current 47 and the stroke of the moveable core, respectively, and the codes assigned there are the same as in Figures 4 and 5. In Figure 6, j and k are the current waveforms of coil 6 for 100 V and 200 V of this example, respectively. With this example, the coil current can be started up sharply as j and k of Figure 6, to supply the pulse series with gradually decreasing ON duty and can be held at a near constant later in the time of switch-on so that attraction of an electromagnet can be performed in a short time and shock due to excess current in the later time of switch-on can be suppressed.

As shown by l in Figure 6, large current can be made to flow at an early time of switch-on and it can be reduced gradually thereafter by a properly set impedance and the pulse width of the coil.

Next, when the coil rated for 100 V is used in this example, as shown by f, g and h of Figures 4 and 5, the pulse width for 200 V is smaller than that for 100 V when connections to 100 V and 200 V are compared. With this example, electricity supplied to the coil can be held near constant, even if the input voltage varies greatly and, at the same time, the pulse width can be controlled regardless of the frequency of input voltage.

A second practical example of this invention is explained with the aid of Figures 7 and 8.

Figure 7 is a block diagram of a major portion of this example and Figure 8 is a waveform chart of various parts of this example. In the example, electromagnet drive circuit 14 is composed of integration circuit 41, voltage detection circuit 42, delay circuit 43, 1st oscillation circuit 52, 2nd oscillation circuit 45 and switching circuit 47. In this example, 1st oscillation circuit 52, which is a switch-on signal generation means, is composed of voltage frequency conversion circuit

49 (hereafter. V/F conversion circuit) that oscillates at a frequency based on the output of 1st integration circuit 41 and an inverter circuit 50 that is connected to the output of V/F conversion circuit 49. In this example, when the input source is switched on and the output voltage of rectifier circuit 2 is sufficient to attract coil 6, voltage detection circuit 42 is operating and output b of Figure 8 is generated and the operations of integration circuit 41 and delay circuit 43 are started. When integration circuit 41 is operating and output d of Figure 8 is generated, V/F conversion circuit 49 generates a pulse series of constant pulse width at a frequency that is nearly proportional to the output of integration circuit 41. The pulse interval of this pulse series is wide and narrow in the start and the end of switch-on, as shown in Figure 8, so that sufficient drive force cannot be produced at the start of switch-on if it is left as is. Therefore, the waveform is inverted by inverter 50 to generate a pulse series with wide and narrow pulse width at the start and end of switch-on as the output of 1st oscillation circuit 52, as shown in k in Figure 8. The 2nd oscillation circuit 45, which is a retention signal generation means, generates a pulse series (g of Figure 8) with a constant frequency and a pulse width that changes with the output of integration circuit 41, similarly to the first practical example.

Switching circuit 47 switches the signal supplied to switching element 5 from the output of 1st oscillation circuit 52 to the output of 2nd oscillation circuit 45 by the use of the output (c of Figure 8) that is generated after a set time from operation start of the delay circuit 43, similarly to the first practical example. Thereby, pulse series l of Figure 8 is supplied to switching element 5. Also, in this example, the coil current can be made almost constant as f in Figure 8, in the later time of switch-on, so that the shock due to the excess amount can be suppressed.

A third practical example of this invention is explained below with the aid of Figures 9-11. In this example, bidirectional thyristor 16 is used as the switching element.

As shown in Figure 9, in this example, coil 6 is connected to the DC output side of diode bridge D_2 that is connected to input source 1. The AC input side of diode bridge D_2 is connected to input source 1 via bidirectional thyristor 16 and the current supplied to coil 6 is controlled through controlling the AC input of bidirectional thyristor 16. As shown in Figure 10, in this example, electromagnet drive circuit 20 is composed of source circuit 3, voltage detection circuit 42, integration circuit 41, 1st oscillation circuit 40, composed of sawtooth-wave generation circuit 44 and comparison circuit 46, switching circuit 57, delay circuit 43, voltage discrimination circuit

58 and gate control circuits 59 and 60. Source circuit 3, voltage detection circuit 42, delay circuit 43 and 1st oscillation circuit 40 are the same as in the first practical example. In this example, the switch-on signal generation means is the 1st oscillation circuit 40 and the retention signal generation means is delay circuit 43.

Switching circuit 57 is composed of two-input AND gate Q_{71}, light-emitting element LD_{71} of photo coupler PC_1 connected to the output terminal of AND gate Q_{71} via resistor R_{71} and inverter Q_{73}, which is connected to one input of AND gate Q_{71}. Two-input AND gate Q_{71}, one input terminal of which is connected to the output terminal of 1st oscillation circuit 40 and the other input terminal of 1st oscillation circuit 40 and the other input terminal is connected to the output terminal of delay circuit 43 via inverter Q_{73}. Thereby, a pulse series corresponding to the output of 1st oscillation circuit 40 is supplied to light-emitting element LD_{71} as the switch-on signal, while the output of delay circuit 43 is at level L, and then supplied to gate-control circuit 59 via photo coupler PC1. When the output of the delay circuit is at level H, the output of AND gate Q_{71} is at level L and this state is transmitted to gate control circuit 59 as a retention signal via photo coupler PC1. That is, in this example, delay circuit 43 also functions as the retention signal generation means.

Gate control circuit 59 is composed of diode bridge D_{91}, Zener diode ZD_{91}, photo transistor PT_{91}, which is the light-receiving element of photo coupler PC1, uni-junction [sic] transistor UT_{91}, thyristor TA_{91}, diodes D_{92}, D_{93}, resistors R_{91}-R_{97} and capacitor C_{91}. Diode bridge D_{91} is connected to input source 1 via resistor R_{91} and generates a DC output, and Zener diode ZD_{91}, connected to the DC output side of diode bridge D_{91} via resistor R_{92}, supplies a constant voltage to subsequent circuits that are connected parallel between its cathode and anode.

The signal from switching circuit 57, electrically insulated, is transmitted to light-receiving element PT_{91} of photo coupler PC1 and uni-junction transistor UT_{91} sends a signal to the gate of thyristor TA_{91} based on such signal; the pulse from the connection and non-connection of said thyristor TA_{91} is supplied to the gate of the thyristor, which is a switching element, via resistor R_{96}.

When the output of delay circuit 43 is at level L, switching circuit 57 supplies a pulse series generated by 1st oscillation circuit 40 to the gate control circuit via photo coupler PC1 and, when the output of delay circuit 43 is at level H, after a set time, the retention signal is transmitted via

photo coupler PC1 so that thyristor 16 connects intermittently, based on the pulse series of the 1st oscillation circuit, as long as the output of delay circuit 43 is at level L, and it becomes disconnected when the output of delay circuit 43 is at level H. Voltage discrimination circuit 58 is composed of Zener diode ZD_{81} that generates standard voltage, comparator Q_{81}, light-emitting element LD_{81} of photo coupler PC2, resistors R_{81}-R_{84} and capacitor C_{81}. Comparator Q_{81} compares the output voltage of rectifier circuit 2 with the standard voltage of Zener diode ZD_{81} and, when the output voltage is lower than the standard value, it lights up light-emitting element LD_{81}. Thereby, light-emitting element LD_{81} lights up for 100 V and stops light emission at 200 V, when two voltages, for example, 100 V and 200 V, are used for the electromagnet drive circuit of this example.

Gate control circuit 60 is composed of bidirectional thyristor PT_{61} which is the light-receiving element of photo coupler PC2 and resistor R_{61}. Photothyristor PT_{61} and resistor R_{61} are connected in series and the main electrode of photothyristor PT_{61}, not connected to resistor R_{61}, is connected to the gate of thyristor 18 and resistor R_{61} is connected to main electrode T_2 of bidirectional thyristor 18. Thereby, photothyristor PT_{61} is connected when light-emitting element D_{61} of photo coupler PC2 emits light and bidirectional thyristor 18, too, is connected. When light-emitting element LD_{61} does not emit light, photothyristor PT_{61} and bidirectional thyristor 18 are disconnected. In this example, coil b is connected to the DC output side of diode bridge D_2 and diode bridge D_2 is connected to input source 1 via bidirectional thyristor 16. In addition, the series circuit of resistor R_1 and capacitor C_1 and the series circuit of resistor R_2, capacitor C_2 and bidirectional thyristor 18 are connected parallel to bidirectional thyristor 16. Thereby, in the beginning time of switch-on, the voltage pulse series of integration circuit 41, the pulse width of which decreases gradually with increase of output voltage of integration circuit 41, is added to coil 6, based on the pulse series generated by 1st oscillation circuit 40. When the output of delay circuit 43 is at level H and switching circuit 57 operates (in retention condition), bidirectional thyristor 16 is disconnected so that voltage from input source 1 is added via impedance of the series connection of resistor and capacitor.

When the voltage of input source 1 is low among the 2 voltages (e.g., it is 100 V), a circuit composed of a series circuit of resistor R_1 and capacitor C_1 and a series circuit of resistor R_2 and capacitor C_2, which are connected parallel, is inserted on the AC input side of diode bridge D_2 in the retention state. The current in coil 6 is thus controlled. When the voltage of input source 1 is

the higher of the 2 voltages (e.g. it is 200 V), bidirectional thyristor 18 is disconnected so that the series circuit of resistor R_1 and capacitor C_1 is inserted on the AC input side of the diode bridge D_2, in the retention state, in order to control the current in coil 6. In this example, resistors R_1, R_2 are set to approximately 60-100 Ω and capacitors C_1, C_2 are set to 0.5 μF - a few μF.

Figure 11 shows the major waveforms of this example. In Figure 11, e is the output of rectifier circuit 2, b is the output of voltage detection circuit 42 and c is the output of delay circuit 43. When the source is switched ON and the output of voltage detection circuit 42 starts up, the output of delay circuit 43 starts up after a set delay time, t_2. A signal of 1st oscillation circuit 40 is supplied to gate control circuit 59 via switching circuit 57 until the output of delay circuit 43 starts up and uni-junction transistor UT_{91} supplies a trigger pulse to the gate of thyristor TA_{91} in synch with such a signal. Thereby, thyristor TA_{91} repeats the connection/disconnection in timing e of Figure 11 and bidirectional thyristor 16, too, repeats connection/disconnection at the same timing. Therefore, the DC output of the diode bridge D_2, controlled by the bidirectional thyristor, has a small control angle during the early time of switch-on, as shown by f in Figure 11 and the control angle increases gradually thereafter. The current in coil 6 starts up sharply in the early time of switch-on, as shown by g of Figure 11 and becomes nearly constant in the later time of switch-on. When output c of delay circuit 43 starts up after delay time t_2, the output of the switching circuit becomes OFF [sic], thereby, uni-junction transistor UT_{91} of gate control circuit 59 stops oscillation, as shown by d in Figure 11, thyristor TA_{91} is disconnected, as shown by e in Figure 11, and bidirectional thyristor 16 is disconnected too. Therefore, the AC input side of diode bridge D_2 is connected to input source 1 via the series circuit of the resistor and capacitor and the output of diode bridge D_2 becomes as f in Figure 11. Under these conditions the current in coil 6 is the retention current of Figure 11g. This is because start-up of the voltage is delayed due to the presence of an L-C series circuit and the impedance of the capacitor is much higher than that of the coil.

With this example, the gate current of the switching element can be supplied directly from input source 1 so that source circuit 3 can be reduced in size. Since the gate control circuit of the switching element is electrically insulated from the switching circuit, etc., an error in operation, due to line noise, etc., can be prevented.

Effect of the invention

This invention can produce an electromagnetic coil excitation circuit that can address a wide range of voltage, ranging from approximately ½ to twice as high by use of a single type of coil of the same voltage rating.

4. Brief explanation of the figures

Figure 1 is a block diagram of the 1st practical example of this invention, for a coil excitation circuit of the electromagnetic contactor.

Figure 2 is a block diagram of an electromagnet drive circuit of the first practical example.

Figure 3 is a circuit diagram showing a specific coil excitation circuit for the electromagnetic contactor of the 1st practical example.

Figures 4 and 5 are waveform charts showing, as an example, the major waveforms for 100 V and 200 V input voltage.

Figure 6 is a waveform chart showing the coil current versus the stroke of the moveable core relationship that corresponds to the input voltage of the 1st practical example.

Figure 7 is a block diagram of the coil excitation circuit for the electromagnetic contactor of the 2nd practical example.

Figure 8 is a major waveform chart of the 2nd practical example.

Figure 9 is a block diagram of the coil excitation circuit for the electromagnet of the 3rd practical example.

Figure 10 is a circuit chart of a specific coil excitation circuit of the 3rd practical example.

Figure 11 is a waveform chart of the 3rd practical example.

2 - rectifier circuit
4, 14, 20 - electromagnet drive circuit

5,1 6 - switching element

6 - coil

40,5 2 - switch-on signal generation means

41 - integration circuit

43 - delay circuit

43 [sic],4 5 - retention signal generation means

47,5 7 - switching circuit

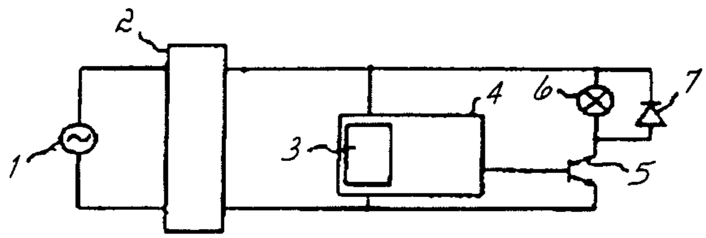


FIG. 1

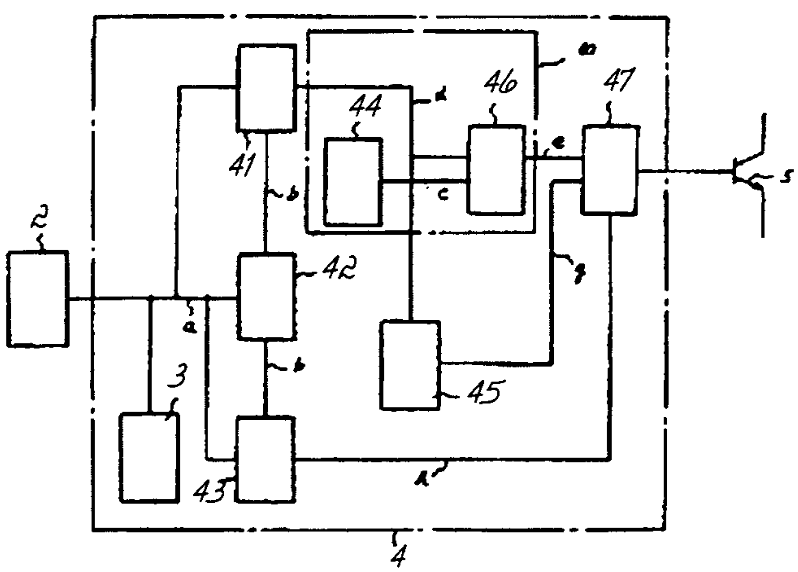


FIG. 2

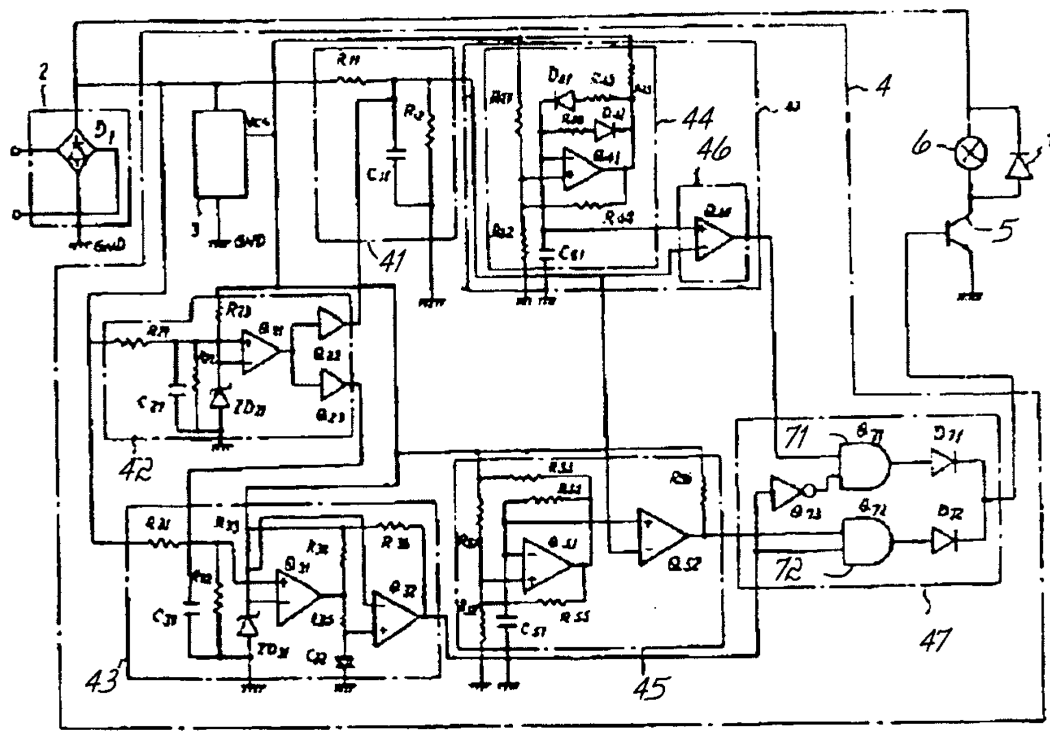


FIG. 3

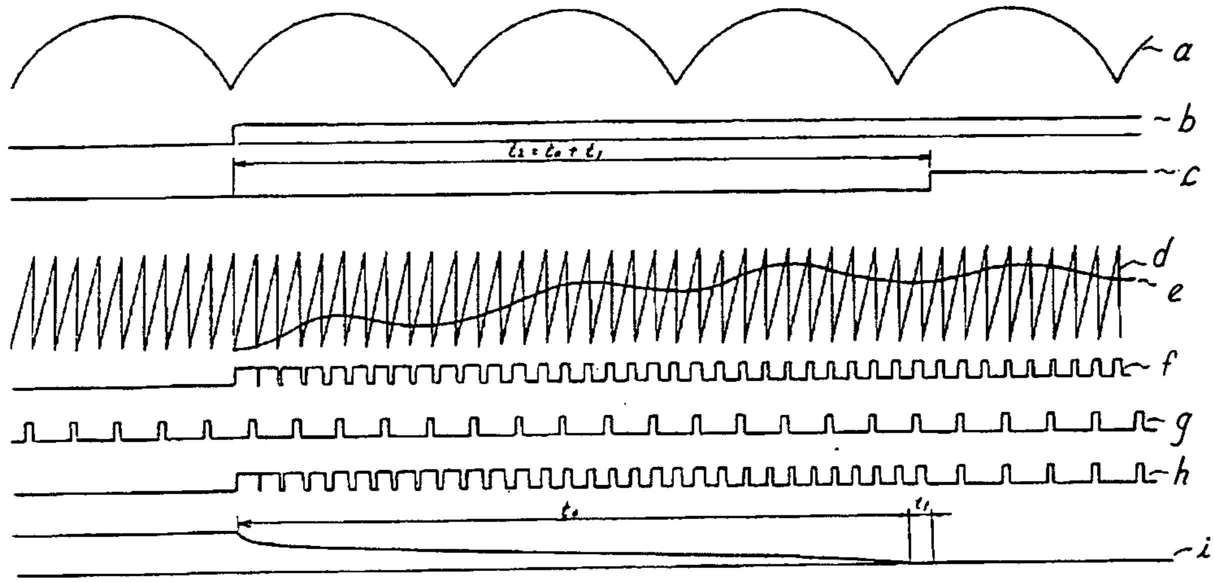


FIG. 4

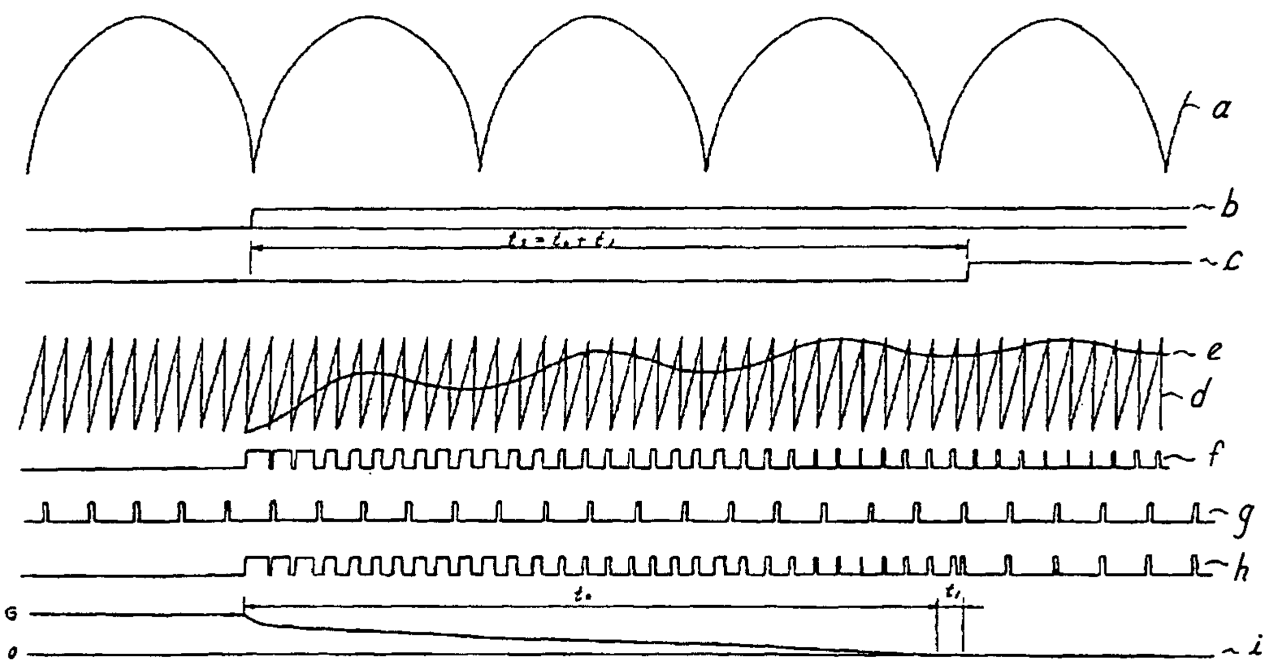


FIG. 5

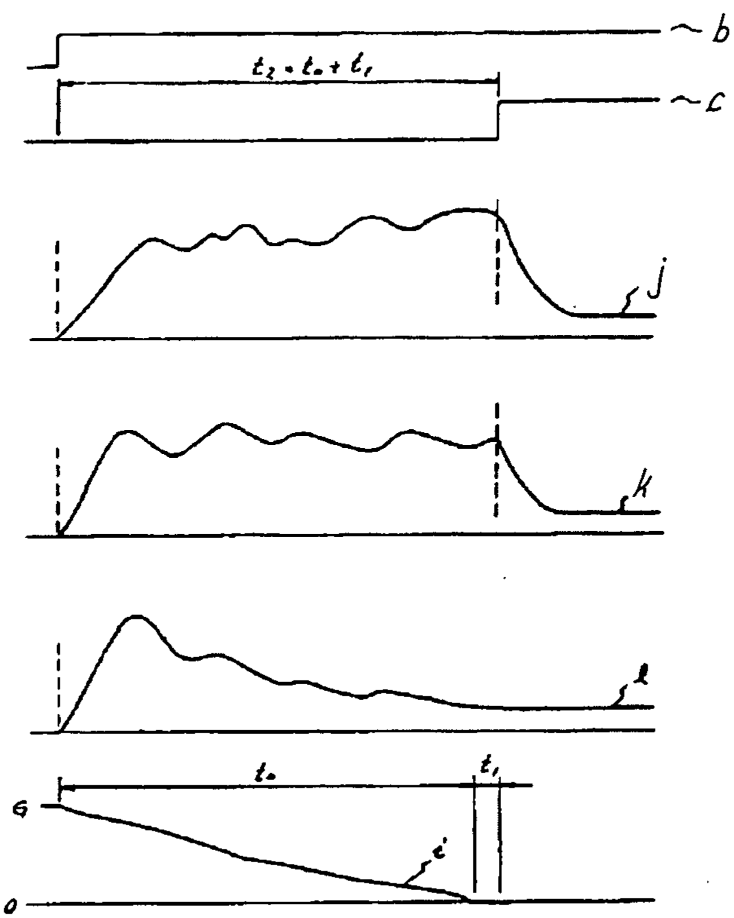


FIG. 6

Figure 7

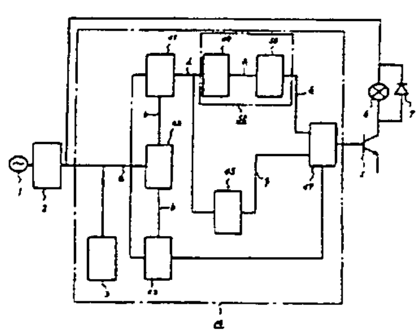


Figure 8

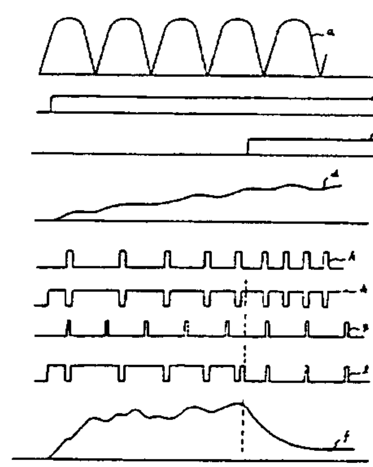


Figure 9

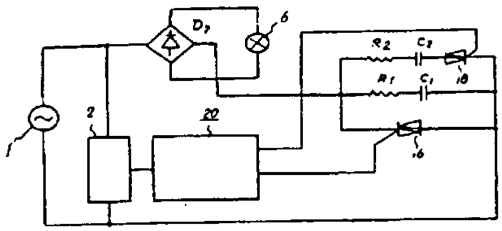


Figure 10

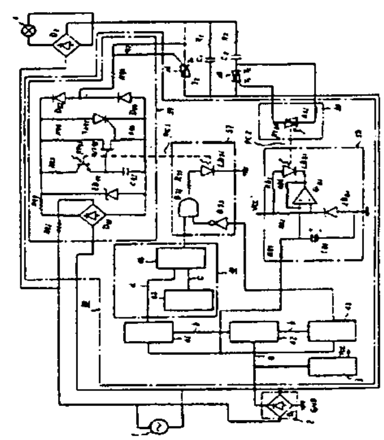
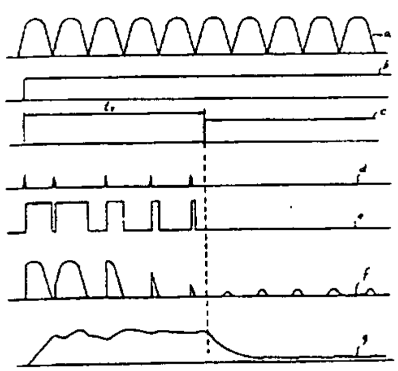


Figure 11



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